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Su Fossu de Cannas Cave (Sadali, central-eastern Sardinia, Italy): the earliest deposit holding Pleistocene megacerine remains in Sardinia

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Resum

Recentment s'han descobert diverses restes de cèrvids als sediments arenosos, vermells i fortament cimentats que omplen la cavitat superior de la Cava Su Fossu de Cannas (Sadali, Sardenya centre-oriental), tallada a les calcàries del Mesozoic de Barbagia di Seulo. Es varen trobar les restes a la part de dalt d'una cova horitzontal, estreta. L'origen d'aquest passadís es pot deure a una fase erosiva antiga (Pleistocè Mitjà?) que va afectar els sediments que primàriament omplien la cova, com s'evidencia per l'erosió del conglomerat superior i la deposició posterior de sediments vermellosos lleugerament cimentats.

Els espècimens analitzats fins ara mostren afinitats morfològiques estretes amb el megacerí endèmic de Sardenya *"Praemegaceros" cazioti* (Depéret, 1897). No obstant això, el cèrvid de Sadali es diferencia del darrer per la seva mida més gran, que supera l'espectre de variabilitat calculat per a l'espècie endèmica, i en alguns trets morfològics (tal com el *corpus mandibulae* fondo i corbat), així com per presentar unes dents proporcionalment més petites i, sobretot, per un metacarpià més gràcil. Els trets peculiars dels espècimens de Sadali suggereixen la seva pertinença a una nova espècie. No obstant això, de moment ens estimem més no batejar-la i anomenar el cèrvid de Sadali "*Praemegaceros*" n. sp., a l'espera de noves dades que permetin afinar la seva diagnosi. El cèrvid de Su Fossu de Cannas es pot considerar com el representant més primitiu del gènere "*Praemegaceros*" a Sardenya i l'ancestre de "*Praemegaceros*" *cazioti*.

Paraules clau. Cèrvid endèmic, Pleistocè, Sardenya, Geomorfologia.

Abstract

Several cervid remains have recently been discovered in the sandy, red-coloured and strongly cemented sediment filling the uppermost cavity of the Su Fossu de Cannas Cave (Sadali, central-eastern Sardinia), cut into the Mesozoic limestone in the Barbagia of Seulo. The remains were found on the ceiling of a narrow, horizontal underground cave. The origin of this passage may be due to an ancient erosional phase (Middle Pleistocene?), which affected the sediments formerly filling up the cave, as evidenced by the erosion of the uppermost conglomerate and by the further deposition of reddish, slightly cemented sediments.

The specimens analysed thus far show close morphological affinities with the endemic Sardinian megacerine *"Praemegaceros" cazioti* (Depéret, 1897). However, the Sadali cervid differs from the latter in its larger size, exceeding the range of variability calculated for the endemic species, and in some morphological features (such as the depth and curved *corpus mandibulae*), as well as in its proportionally smaller teeth and, notably, its elongated, slender metacarpal. The peculiar features of the Sadali specimens suggest its attribution to a new species. Nevertheless, for the moment, we prefer to name the Sadali cervid "*Praemegaceros*" n. sp., awaiting new data to present the diagnosis. The Su Fossu de Cannas cervid can be regarded as the most primitive representative of the genus "*Praemegaceros*" in Sardinia and the ancestor of the endemic species "*Praemegaceros*" *cazioti*.

Key Words. Endemic cervid, Pleistocene, Sardinia, Geomorphology.

Introduction

In the Pleistocene of Sardinia, cervid remains, generally ascribed to *"Megaceroides"* or "*Megaloceros*" or "*Praemegaceros*" *cazioti* (Depéret, 1897) [see Palombo (2005) for a discussion regarding nomenclature], are relatively common, mainly in eolianites or in cave deposits, attributed for the most part to the Late Pleistocene (e.g., Dehaut, 1911; Comaschi Caria, 1955; 1956; Azzaroli, 1962; Cordy & Ozer, 1973; Caloi & Malatesta, 1974; Caloi *et al.*, 1981; Klein Hofmeijer, 1997; Antonioli *et al.*, 1998; Ginesu *et al.*, 1998; Melis *et al.*, 2002; Abbazzi *et al.*, 2004; Palombo, unpublished data) (Fig. 1).

The earliest occurrence of megacerini in Sardinia thus far reported is recorded in the karst fissures "XI canide" and "XI mar2002" opening up at Monte Tuttavista

Fig. 1. Map of distribution of the most important *"Praemegaceros"* remains in Sardinia.

Fig. 1. Mapa de distribució de les restes més importants de "Praemegaceros" *a Sardenya.*

(Orosei), tentatively attributed to the early Middle Pleistocene (Ginesu & Cordy, 1997; Sondaar, 2000; Abbazzi *et al.*, 2004; Palombo, in press), and from the Santa Lucia quarry (Iglesias) (proposed age 450 ± 90 ka BP, ESR date on cervid tooth enamel, Motoji Ikeya, *fide* van der Made, 1999) (van der Made & Palombo, in press)

Scanty cervid remains were recorded from Capo Figari II, in a fissure filling when an archaic arvicolid also occurred (*"Tyrrhenicola"* sp., Brandy, 1978). The proposed age is 366,959 +/- 20% years BP (ESR date on cervid tooth enamel, Motoji Ikeya, *fide* van der Made, 1999).

Since its first identification by Depéret in 1897 of the cervid remains found at Nonza, in Corsica, *"P." cazioti"* has been reported at several Sardinian and Corsican sites ranging in age from the late Middle Pleistocene to the Holocene (e.g., Caloi & Malatesta, 1974; Bonifay *et al.*, 1998; Pereira *et al.*, 2005).

Though the endemic cervid from Sardinia and Corsica is quite a well-known species, specialists still do not agree on the taxonomy and phylogenetic relationships of this taxon, which was assigned either to a new genus or regarded as phylogenetically related to *Dama, Eucladoceros* or megacerine deer (e.g., Radulesco & Sampson, 1965; Caloi & Malatesta, 1974; Klein Hofmeijer, 1997; van der Made, 1999; 2003; Sondaar & van der Geer, 2002; etc.), commonly believing that only one phyletic line was present in Sardinia, perhaps represented by more than one chrono-subspecies. The hypothesis of derivation from megacerines belonging to the *"Praemegaceros" verticornis* group is currently widely accepted, as supported by skull and mandible features (see below). In Corsica, in addition to the megacerini, a cervid closely related to red deer has been reported (*Cervus elaphus rossii* Pereira, 2001).

The discovery in the Su Fossu de Cannas Cave (Sadali, central-eastern Sardinia) (Figure1) of cervid remains larger than the Middle and Late Pleistocene endemic

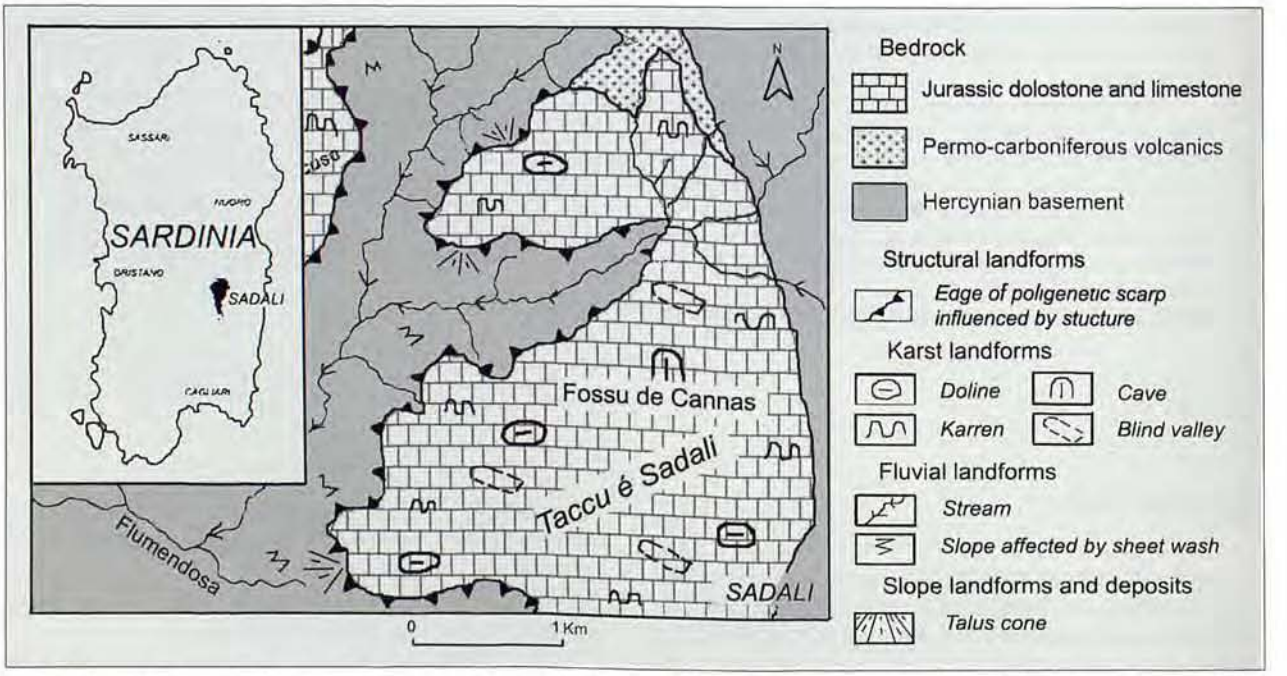

Fig. 2. Su Fossu de Cannas cave location and schematic geological map of the Sadali area.

Fig. 2. Localització de la cova Su Fossu de Cannas i esquema geològic de l'àrea de Sadali.

cervid, and similar in size to those of *Cervus elaphus*, has thus been considered an extremely interesting element. In-deed, our preliminary analysis demonstrated that the cervid specimens from Sadali showed significant morphological affinity with "*Praemegaceros*" *cazioti* (Palombo *et al.*, 2003).

Consequently, in keeping with a graded trend to increase the size in small-bodied species and to dwarfism in large-bodied, characterising flightless non-marine mammals inhabiting islands (the "island rule" by Foster (1964) and following reformulation, as in Brown & Lomolino, 1998), we can suppose that the Sadali cervid, if actually older, was the ancestor of the Middle and Late Pleistocene Sardinian megacerini.

The aim of this paper is to evaluate, on the basis of geomorphogical data, the possible age of the fossiliferous deposits in Su Fossu de Cannas Cave and to illustrate which of the peculiar features of cervid remains recognised thus far correspond to plesiomorphic characteristics.

Geomorphologic Framework

The limestone plateau of Sadali, located in central-eastern Sardinia, is one of a series of plateaus (the so-called "Tacchi") characterised by fully developed karst forms. In this area, Mesozoic dolomitic limestone sediments cover the "post-Hercynian peneplain" lying on a metamorphic Palaeozoic basement (Fig. 2).

The geomorphological evolution of the "Tacco di Sadali," in which the Su Fossu de Cannas Cave lies, has been greatly conditioned by endogenous factors. Tertiary and Plio-Pleistocene distensive tectonic movements have influenced the development of the hydrographic network and both deep and superficial karst evolution.

The most frequent among small karst forms are the karren-type microforms on the surfaces of bare rock. The most common types are the rund-karrens, flat or sometimes protruding due to the presence of well-rounded

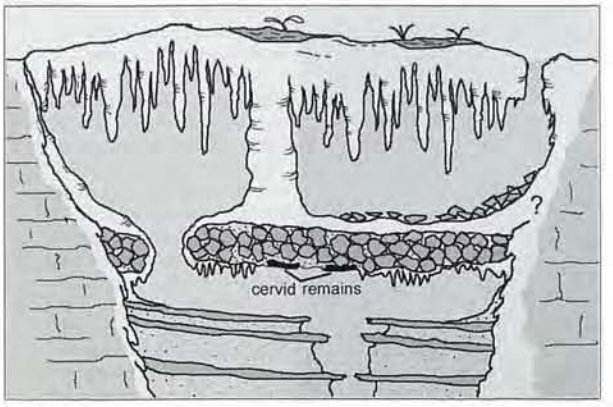

Fig. 3. Longitudinal section of Su Fossu de Cannas cave.

Fig. 3. Tall longitudinal de la cova Su Fossu de Cannas.

Fig. 4. Su Fossu de Cannas Cave: the entry of the underground cave; the stalagmitic concretions cover the conglomeratic deposit.

Fig. 4. Cova Su Fossu de Cannas: entrada a la cova. Les concrecions estalagmítiques cobreixen el dipòsit de conglomerats.

Fig. 5. Su Fossu the Cannas Cave; ceiling of the horizontal underground cave: Some bones are identifiable under the flowstone.

Fig. 5. Cova Su Fossu de Cannas: reblit de la cova horitzontal. S'identifiquen alguns ossos sota les concrecions calcàries.

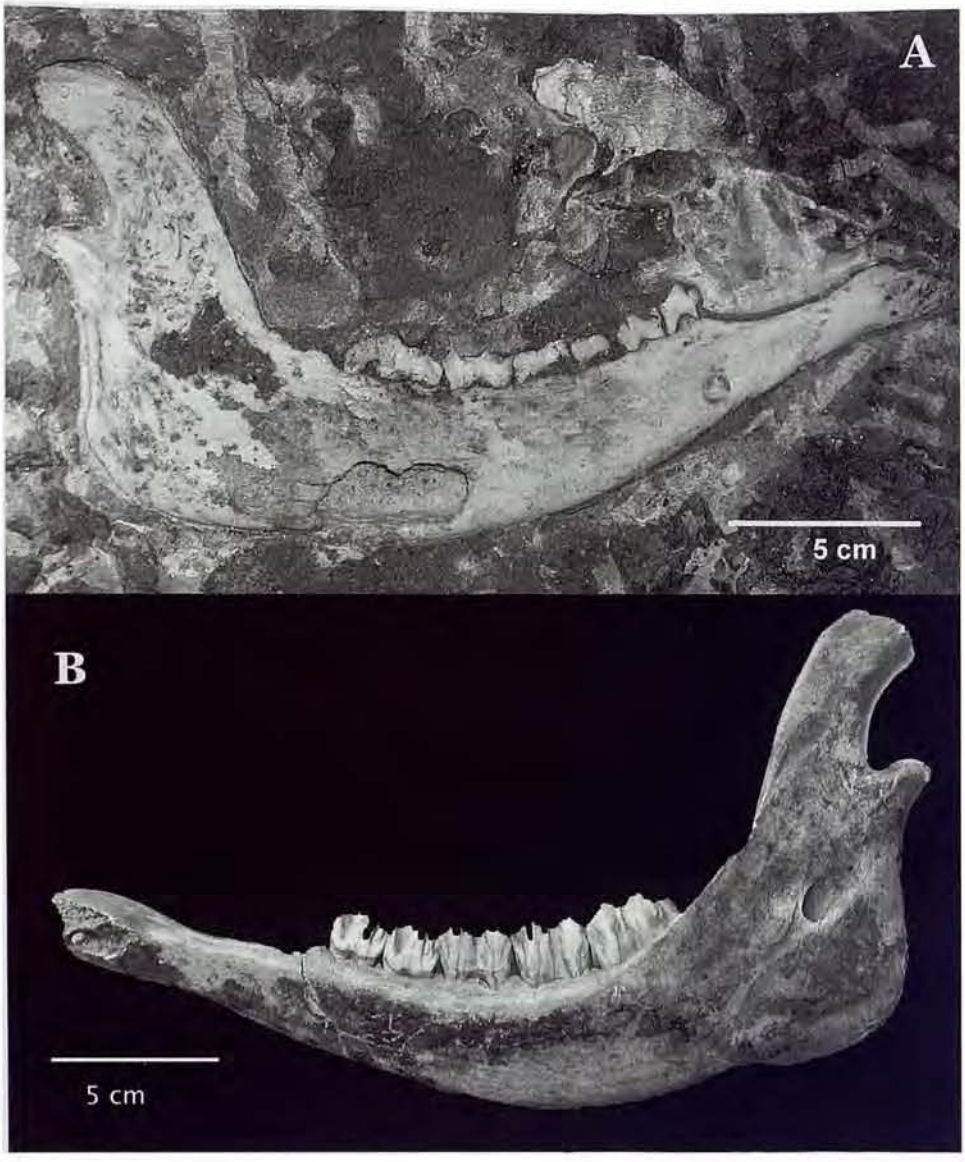

Fig. 6. a) "*Praemegaceros*" n. sp. from Su Fossu de Cannas Cave): left jaw in lingual view. b) "*Praemegaceros*" *cazioti*, Dragonara cave, SI.

Fig. 6. a) "Praemegaceros" *n. sp. de la Cova de Su Fossu de Cannas: mandíbula esquerra en norma lingual. b)* "Praemegaceros" cazioti, *Cova de Dragonara, SI.*

spikes. In the central sector of the plateau, there are several dolines caused by dissolution or collapse and small blind valleys preferentially aligned in a NE-SW direction (Fig. 2). The dolines are separated by conical, truncated-conical or in some cases "tower-shaped" rises. These rises may be interpreted as residual forms of intense, prolonged dissolution processes.

Subterranean karst phenomena are characterised by numerous, at times very extensive, cavities affected by phenomena of physical and chemical filling, with extremely variable, significant, primary and secondary morphologies.

The evolution of almost all the cavities present on the plateau has been clearly conditioned by the faulting and position of calcareous banks. Cave development is prevalently horizontal with slight inclination, and is sometimes affected by lateral complexity.

Su Fossu de Cannas Cave

Su Fossu de Cannas Cave is located in the central sector of the Sadali limestone plateau, near a small rise between two small dry valleys (Fig. 2) (Bartolo *et al.*, 1995). On the surface, near the present entrance to the cave, small dolines caused by collapse and numerous remains of flowzones and stalactites are present. The latter represent the remains of cavities brought to light by intense processes of selective erosion and alteration of Mesozoic limestone.

In the cave, only partially explored and still under study, some indefinable speleogenetic episodes can be recognised. Its basic origin is linked precisely to karst dissolution processes and clastic filling triggered by a water supply. Due to variations in climate and the water regimen, erosion and sedimentation phenomena, both chemical and caused by low-energy water flow, subsequently took place.

In spite of modifications due to the morphological evolution it has undergone, the cave has been greatly influenced by the structural geological conditions of the site. From the present entrance, a narrow opening, one enters the first, horizontally- developed room, highly concretionary and aligned along a NW-SE fault. This first cavity, with its lateral branches almost totally filled with fine sedi-

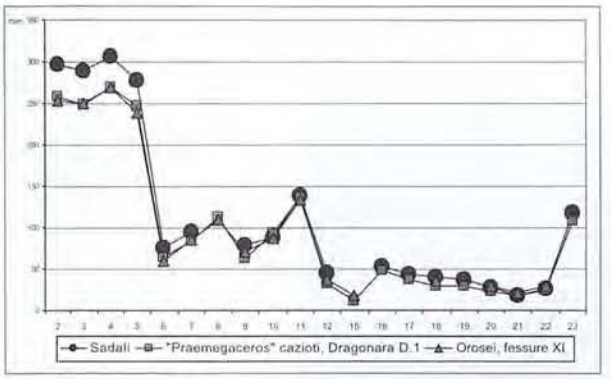

Fig. 7. Comparison of the mandibulae dimensions of *"Praemegaceros" cazioti* specimens (Depéret, 1897) from Dragonara (MPUR 1/235, Palaentological Museum, University "La Sapienza" of Rome), of the unpublished cervid from Cave XI on Monte Tuttavista (Orosei) ("Soprintendenza ai Beni Archeologici di Sassari e Nuoro") and "*Praemegaceros*" n. sp. from the Su Fossu de Cannas Cave (Sadali, Nuoro): **2** = Incisors-condylus distance; **3** = Incisors-*angulus mandibulae* distance; **4** = Incisors- coronoid apophysis distance; **5** = Distance between the incisors and the posterior edge of vertical branch; **6** = Distance between M_3 and posterior edge oh of vertical branch; **7** = M_3-condylus distance; **8** = M_3-coronoid apophysis distance; **9** = Incisors-P_2 distance; **10** = Height at condylus; **11** = Height at coronoid apophysis; **12** = Distance coronoid apophysis-condylus **16** = Height (internal) of *corpus mandibulae* behind M_3; **17** = Height (internal) of *corpus mandibulae* at M2-M1; **18** = Height (internal) of *corpus mandibulae* under P_4; **19** = Height (internal) oh *corpus mandibulae* under P_3; **20** = Height oh *corpus mandibule* at P_2 (anterior); **21** = Minimum height oh horizontal ramus; **22** = Distance incisors-condylus, Distance incisors-P_2x100 ratio.

Fig. 7. Comparació de les dimensions mandibulars dels espècimens de "Praemegaceros" cazioti *(Depéret, 1897) de Dragonara (MPUR 1/235, Museu Paleontològic de la Universitat "La Sapienza" de Rome), del cèrvid no publicat de Cave XI a Monte Tuttavista (Orosei) ("Soprintendenza ai Beni Archeologici di Sassari e Nuoro") i* "Praemegaceros" *n. sp. de Su Fossu de Cannas Cave (Sadali, Nuoro):* **2** *= Distància incisives-còndil;* **3** *= Distància incisives-*angulus mandibulae*;* **4** *= Distància incisives- apòfisi coronoide;* **5** *= Distància entre les incisives i la vorera posterior de la branca vertical;* **6** *= Distància entre M_3 i la vorera posterior de la branca vertical;* **7** *= Distància M_3-còndil;* **8** *= Distància M_3-apòfisi coronoide;* **9** *= Distància incisives-P_2;* **10** *= Alçària al còndil;* **11** *= Alçària a l'apòfisi coronoide;* **12** *= Distància apòfisi coronoide-còndil* **16** *= Alçària (interna) del* corpus mandibulae *rere l'M_3;* **17** *= Alçària (interna) del* corpus mandibulae *a nivell de M_2-M_1;* **18** *= Alcària (interna)* corpus mandibulae *sota el P_4;* **19** *= Alçària (interna) del* corpus mandibulae *sota el P_3;* **20** *= Alçària (interna) del* corpus mandibulae *sota P_2 (anterior);* **21** *= Alçària mínima de la branca horitzontal;* **22** *= Distància incisives-còndil / Distància incisives-P_2 x 100.*

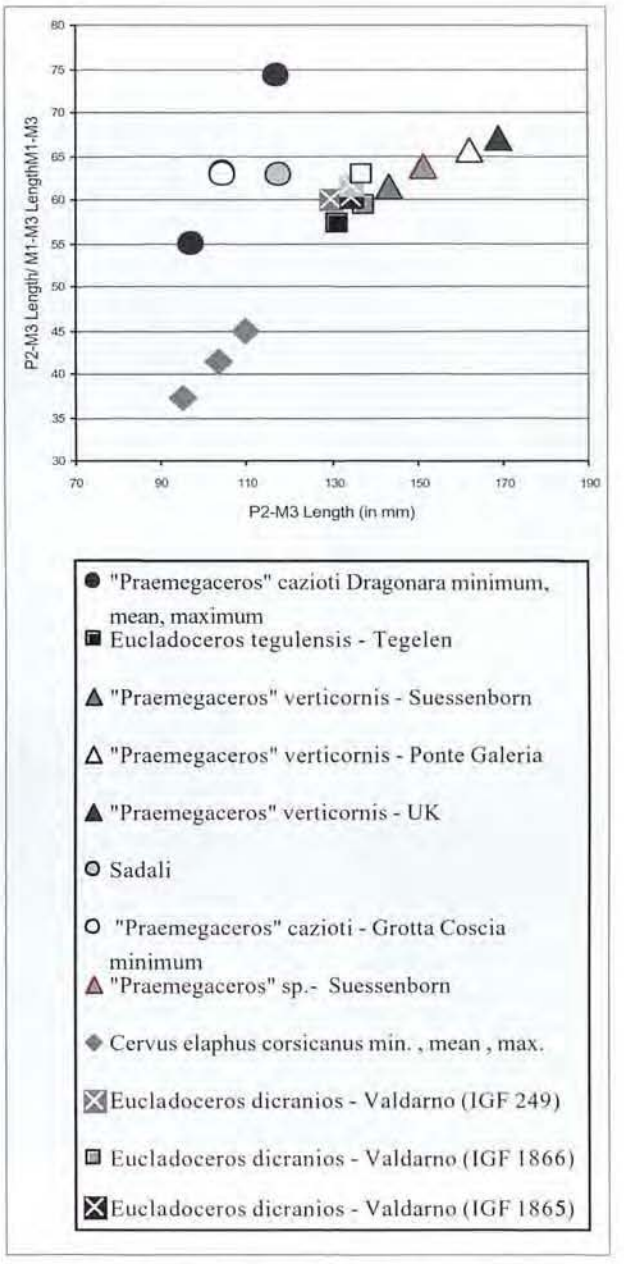

Fig. 8. Scatter diagram of the value of the index ratio "Length of premolar row" / "Length of molar row" (P_2-P_4/M_1-M_3 x 100) *versus* "Length of dental row" (P_2-M_3) in the "*Praemegaceros*" n. sp from Su Fossu de Cannas Cave (Sadali, Nuoro) cervid, in "*Praemegaceros*" *cazioti* (Depéret, 1897) from Sardinia (Dragonara, post-Tyrrhenian) and Corsica (Coscia Cave, Last Glacial, Pereira & Bonifay, 1998), in some endemic cervids, in middle-sized and large cervids from the Pliocene and Pleistocene of Europe (Azzaroli & Mazza, 1992; Kahlke, 1956-59; 1958; 1969; Kahlke, 1997; Kostopoulos, 1997; Leonardi & Petronio, 1974; 1976; Spaan, 1992; Palombo, unpublished data).

Fig. 8. Diagrama de dispersió del valor de l'índex "Llargària de la sèrie premolar"/"Llargària de la sèrie molar" (P_2-P_4/M_1-M_3 x 100) versus la "Llargària de la sèrie dentària" (P_2-M_3) al cèrvid "Praemegaceros" *n. sp. de la Cova Su Fossu de Cannas (Sadali, Nuoro), a* "Praemegaceros" cazioti *(Depéret, 1897) de Sardenya (Dragonara, post-Tirrenià) i Còrsega (Cova de Coscia, Darrer Glacial, Pereira & Bonifay, 1998), a alguns cèrvids endèmics, i a cèrvids de mida mitjana i gran del Pliocè i Pleistocè d'Europa (Azzaroli & Mazza, 1992; Kahlke, 1956-59; 1958; 1969; Kahlke, 1997; Kostopoulos, 1997; Leonardi & Petronio, 1974; 1976; Spaan, 1992; Palombo, dades no publicades).*

ment, is characterised by a thick column located about 8 m from the entrance and by a strongly-cemented conglomerate floor, interrupted in its final stretch by a narrow shaft about 1 m deep. In the external wall of this first room, a carbonate outflow coming from a now-blocked fissure covers what is probably a residue of the floor (Fig. 3).

From the base of the shaft, a narrow, horizontal underground passage is entered; its ceiling is made of the same conglomerate as the floor of the first cavity (Fig. 4).

The floor of this passage is made up of carbonate hardpan about 30cm thick, interrupted by small collapsed areas. This hardpan lies on a thick layer of fine, sandy, red-coloured sediment, with intercalated carbonate deposits, which probably represent the filling of a vast cavity.

On the ceiling of this passage, several remains belonging to middle/large -sized cervids are encased in a fine, red, calcareous, very strongly cemented matrix, underlying the conglomerate.

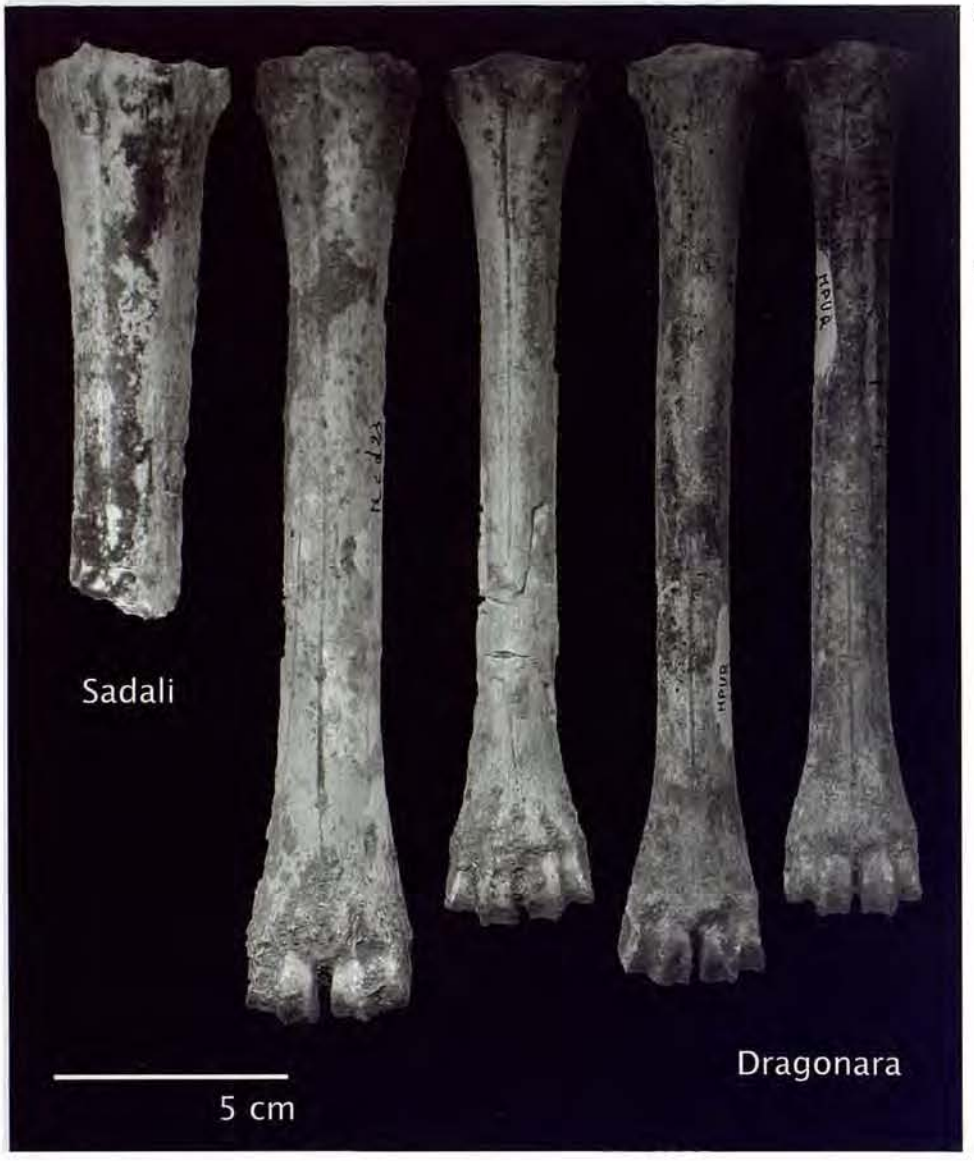

Fig. 9. Dorsal view of metacarpal of "*Praemegaceros*" n. sp. from Su Fossu de Cannas Cave compared with the smallest and greatest, most slender and most robust metacarpals recognised in the sample of "*Praemegaceros*" *cazioti* from Dragonara cave.

Fig. 9. Vista dorsal del metacarpià de "Praemegaceros" *n. sp. de la Cova Su Fossu de Cannas comparat amb els metacarpians més petit i més gran, més prim i més robust, de la mostra de* "Praemegaceros" cazioti *de la cova Dragonara.*

Discussion

Our preliminary analysis has pointed out the presence of a vast cavity affected by several sedimentation and erosion stages. The conglomerate, whose origin can be attributed to quite a high-energy water flow coming from outside, probably represents what remains of the final filling of the cavity. Subsequently, cementing processes protected the conglomerate from an erosion stage during which partial emptying out of the cave probably occurred.

The presence of scarce remains of reddish, slightly cemented sediments in the cracks of speleothemes found in the walls of the lower passage witness to erosional processes affecting the fine sediments underlying conglomerate. A preliminary micromorphological study of these deposits has shown that we are dealing with fine laminated sediments. The laminas show normal gradation with well-selected quartz granules at the base, while towards the top, the clayey matrix increases until it is dominant on the ceiling. These characteristics make one presume a fining-upward-type of sedimentation with low-energy water.

At present, no elements have been found that permit the determination of the age of the different deposits. In any case, from sediment characterisations, the degree of cementing and stratigraphic relationships, we can hypothesise that the conglomerate accumulated after deposition of the levels in which the cervid remains occur, probably during a phase of renewed high-energy water, as indicated by the dimensions and the extent of rounding of clastic limestone.

The cervid remains

Several cervid remains, covered and masked by massive calcareous concretions, are partially visible on the ceiling of the tunnel; they apparently belong to moderately disarticulated skeletons with no evident anatomical

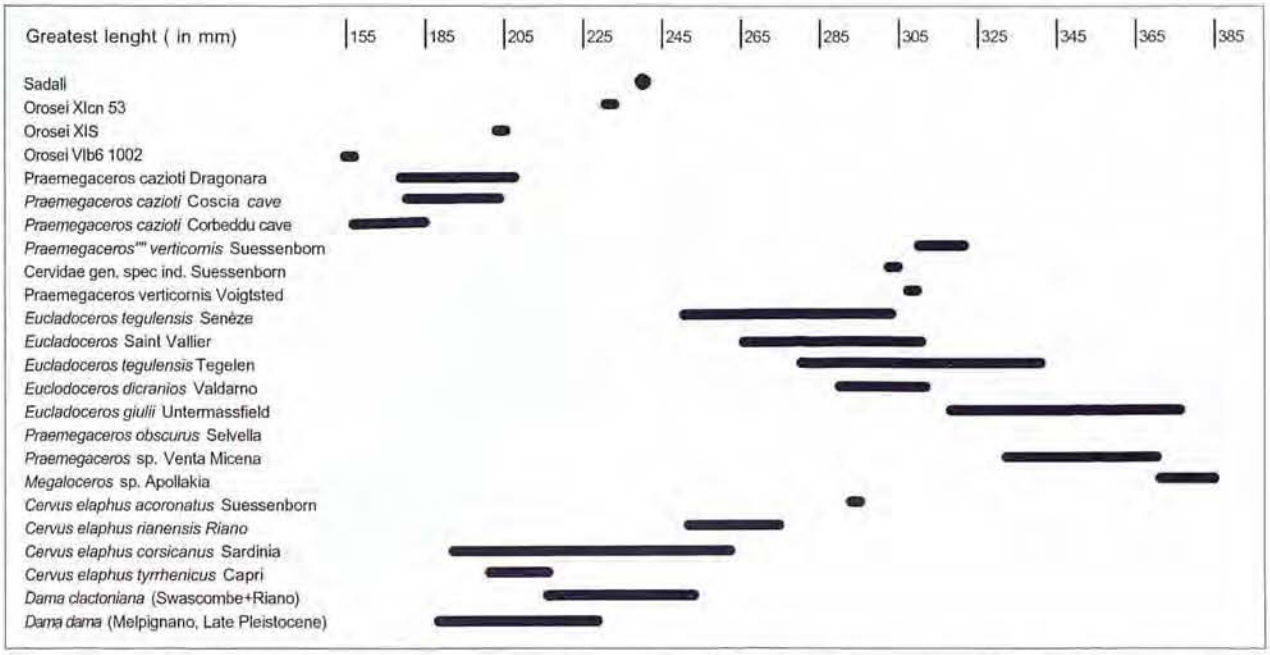

Fig. 10. Maximum length metacarpal of "*Praemegaceros*" n. sp. from Su Fossu de Cannas Cave (measured in situ) compared with metacarpal length and variability ranges of *"Praemegaceros" cazioti* (Depéret, 1897) from Sardinia (Dragonara, post-Tyrrhenian; Corbeddu Cave, Late Glacial, Hofmeijer, 1997) and Corsica (Coscia Cave, Last Glacial, Pereira & Bonifay, 1998), some endemic middle-sized and large cervids from the Pliocene and Pleistocene of Europe (Azzaroli & Mazza, 1992; Kahlke, 1956-59; 1958; 1969; Kahlke, 1997; Kostopoulos, 1997; Leonardi & Petronio 1974, 1976; Spaan, 1992; Di Stefano, 1994; Palombo unpublished data).

Fig. 10. Llargària màxima metacarpiana de "Praemegaceros" *n. sp. de la Cova Su Fossu de Cannas (mesurada in situ) en comparació amb la llargària metacarpiana i els marges de variabilitat de* "Praemegaceros" cazioti *(Depéret, 1897) de Sardinia (Dragonara, post-Tirrenià; Cova Su Corbeddu, Darrer Glacial, Hofmeijer, 1997) i Còrsega (Cova de Coscia, Darrer Glacial, Pereira & Bonifay, 1998), a alguns cèrvids endèmics de mida mitjana i gran del Pliocè i Pleistocè d'Europa (Azzaroli & Mazza, 1992; Kahlke, 1956-59; 1958; 1969; Kahlke, 1997; Kostopoulos, 1997; Leonardi & Petronio, 1974; 1976; Spaan, 1992; Palombo, dades no publicades).*

connection (Fig. 5). Such a preservation pattern is quite common in vertebrate-bearing fluvial channel deposits associated with ribbon sand sediments resulting from streams with slight bank erosion and minimum alluvial sediment reworking *(channel fill mode)*. Moreover, this taphonomic pattern can be associated with the transport or moderate reworking of carcasses by subterraneous low fluvial streams. A taphonomicaly comparable assemblage was recently identified in Nurighe cave (northwestern Sardinia) (Ginesu *et al.*, 1998; www.nurighe.it, 2003).

The most important remains thus far uncovered are the lingual side of a left jaw (Fig. 6a) and a right metacarpus. During a preliminary survey carried out in 2002 in collaboration with the "Soprintendenza per i Beni Archeologici per le province di Sassari e Nuoro", we could retrieve only the proximal epiphysis of the metacarpus (the distal part is still retained in the sediment), a proximal part of a femur and a patella. These bones, and other skeletal elements not clearly identifiable, probably belong to a single individual, a female as inferred from the lateral profile of an atlas uncovered near the condylus of the mandible.

Description

Mandible

The morphological features of the jaw are similar to those characterising the *"Praemegaceros" cazioti* specimens from Dragonara Cave (Fig. 6a), as shown by: the clearly convex lower profile; the curved alveolar limbus with the occlusal line of the tooth-row placed under the alveolar line of incisor teeth; the relatively short diastema; the massive horizontal *corpus mandibulae* with fairly weak pachyostosis; the high position of *condylus madibulae.*

The Sadali mandible, however, differs from Dragonara specimens (Fig. 6b) in its more massive *corpus mandibulae*, which extends considerably backwards, rather like a bovid. The lower profile of the *corpus mandibulae* is more regularly convex, and apparently lacks any concavity in its inferior outline in the region of the *impressio vasculosa.* Moreover, the vertical *ramus* is proportionally shorter and the diastema slightly longer (Fig. 7).

We can observe only the lingual side of teeth, less hypsodont and proportionally smaller than the specimens from Dragonara: the length of the toothrow (L_c P_2-M_3 =117.5 mm; L_c = length measured at the base of crow) is very similar to the greatest length obtained for Dragonara specimens (117.08 mm).

Moreover, the premolars are proportionally smaller, as expressed by the value of the "length of premolar row/length of molar row" index (Fig. 8).

Metacarpus

The morphology of the proximal articular surface of the metacarpus is similar to those characterising *"Praemegaceros" cazioti* specimens from Dragonara: the articular surface for the *capitatum* is large, with a slightly curved anterior profile; its posterior edge extends to con-

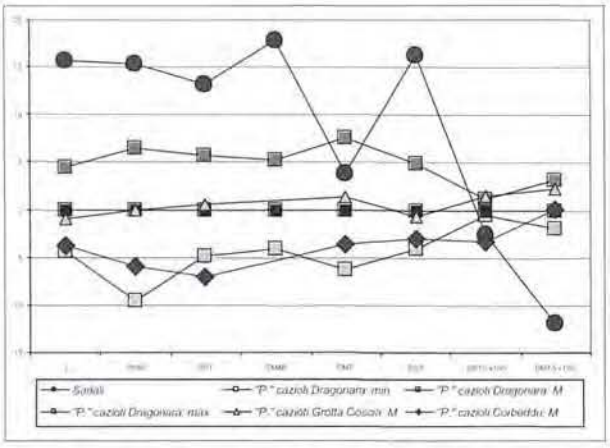

Fig. 11. Metacarpi - Logarithmic distances of the principal dimensional values of the metacarpus from of "*Praemegaceros*" n. sp. from Su Fossu de Cannas Cave and of "*Praemegaceros*" *cazioti* from Dragonara, Corbeddu Cave (Hofmeijer, 1997) and Coscia Cave (Pereira & Bonifay, 1998) (standard = average values of Dragonara sample).

Fig. 11. Metacarpians – Distàncies logarítmiques dels principals valors mesurats dels metacarpians de "Praemegaceros" *n. sp. de la Cova Su Fossu de Cannas i de* "Praemegaceros" cazioti *de la Cova Dragonara, Cova de Su Corbeddu (Hofmeijer, 1997) i de la Cova de Coscia (Pereira & Bonifay, 1998) (standard = valors mitjans de la mostra de Dragonara).*

nect laterally with the postero-mesial edge of the articular surface for the *uncinatum*). However, the metacarpus of the Su Fossu de Cannas Cave cervid differs from Sardinian and Corsican megacerini in its slenderness and notably larger size (Fig. 9).

Its length, in fact, is more than 26% greater than the maximum length estimated for the metacarpus of the Dragonara sample and 29.8% greater than the standard, clearly placing it outside both the real (170-208 mm) and theoretical (162.2-213.8 mm) variability ranges calculated for this sample. The length of the metacarpus from Sadali falls within the variability range of smaller *Eucladoceros* representatives, such as the Senèze and Saint Vallier middle Villafranchian samples, as well as in the range of the large red deer reported from the late Middle Pleistocene of the Latium area (*Cervus elaphus rianensis*, Leonardi & Petronio, 1974). On the other hand, the Sadali metacarpus is smaller than those of the early Middle Pleistocene megacerini belonging to the "*Praemegaceros*" *verticornis* group, as well as of the large late Early Pleistocene cervids ascribed to the genus *Eucladoceros*, "*Praemegaceros*", *Megaloceros*, and larger than Mediterranean endemic red deer and Clacton fallow deer (Fig. 10). Moreover, the Sadali metacarpus is elongated and clearly more slender than those of "*Praemegaceros*" *cazioti* from Sardinia and Corsica; the dyaphysis and, perhaps, the proximal epiphysis (unfortunately partially damaged) show reduced transversal diameter. The slenderness of the dyaphysis is also confirmed by the robusticity index (DMT/L x 100), whose value is clearly inferior to the minimum calculated for the Dragonara sample, so that the Sadali metacarpus appears thinner than the thinnest females among the Dragonara specimens (Fig. 11). In addition, the distal epiphysis is more slender than those of megacerini ascribed to the "*Praemegaceros*" group, with the exception of the specimens from Venta Micena (Menendez, 1987), slender, and Apollonia (Kostopoulus, 1997), quite similar (Fig. 12). Principal component multivariate analysis (Fig. 13) confirms the difference in proportions between the Sadali metacarpus and "*P.*" *cazioti* specimens from the Dragonara, Corbeddu and Coscia caves.

Moreover, it is worth noticing that the Orosei specimens are also set apart from the abovementioned "*P.*" *cazioti*. These metacarpi, as well as the Sadali one, seem to have global proportions more similar to those of the small middle Villafranchian *Eucladoceros* from Senèze and Saint Vallier. The stout metacarpi of German "*Praemegaceros*" *verticornis* from Voigstedt and Süsserborn are clearly separate (Fig. 12, 13).

Femur

The most significant feature of the proximal portion of the femur is its large size (Fig. 14, 15). The Sadali specimen shares some distinctive morphological features with Dragonara femurs, such as great medial extension of the caput, lateral inclination of the greater trochanter and a reduced lesser trochanter. However, the axis of the caput forms a wider angle with the dyaphysis, and the trochanter is, consequently, higher. Taking into account the incompleteness of the specimens, we cannot understand the real meaning of this characteristic that, *per se*, would suggest a minor cursorial aptitude than the Dragonara cervid (Köhler, 1993; Kappelman *et al.*, 1997).

Discussion

The cervid remains of the Su Fossu de Cannas Cave show morphological affinity with those referring to the endemic "*Praemegaceros*" *cazioti* species, but they are larger in size than the Late Pleistocene specimens from Dragonara and similar to or slightly larger than the Middle Pleistocene "*Praemegaceros*" sp. from the fissure infillings at Monte Tuttavista.

The morphology of the jaw from Sadali on the one hand confirms both the affinities (short diastema extending upwards, curved, quite robust horizontal corpus) and the differences (reduced pachyostosis) between the endemic cervid from Sardinia and Corsica and the continental megacerini belonging to the "*Praemegaceros*" *verticornis* group; on the other, it highlights the differences between the former and continental deer belonging to the *Eucladoceros* genus.

Indeed, after the results of re-examination of skulls from Sardinian specimens from Dragonara (Caloi & Malatesta, 1974), Maritza (Cordy & Ozer, 1972) and Porto Vesme (Comaschi Caria, 1955), the basic cranial structure of the "*Praemegaceros*" *cazioti*, seems to confirm its greater affinity with representatives of the "*Praemegaceros*" genus. The Sardinia megacerine shares a typical forehead morphology with continental ones: flat, slightly convex frontal bones, the position and direction of the peduncles (though the beam is straighter and oriented more laterally and distally than that of typical antlers of cervids belonging to the "*Praemegaceros*" *verticornis* group, as shown by specimens from the Early Pleistocene Apollonia 1 site, Greece, referred to as "*Megaloceros*" sp. by Kostopoulus, 1997), the shape of the brain case, the angle between the basioccipital and palatine bones and

Fig. 12. Metacarpi – Scatter diagrams of : a) breath of proximal epiphysis against greatest length of metacarpus; b)minimal breath of shaft against greatest length of metacarpus antero-posterior diameter against transversal diameter of distal metacarpus c) breath of distal epiphysis against greatest length of metacarpus ; d) antero-posterior diameter against transversal diameter of distal metacarpus in "*Praemegaceros*" n. sp. from Su Fossu de Cannas Cave, "*Praemegaceros*" *cazioti* (Depéret, 1897) from Sardinia (Dragonara, post-Tyrrhenian; Corbeddu Cave, Tardiglacial, Hofmeijer, 1997) and Corsica (Coscia Cave, Last Glacial, Pereira & Bonifay, 1998), in endemic middle-sized red deer from Sardinia and Capri and in selected large cervids from the Pliocene and Pleistocene of Europe (Azzaroli & Mazza, 1992; Kahlke, 1956-59; 1958; 1969; Kahlke, 1997; Kostopoulos, 1997; Leonardi & Petronio 1974; 1976; Spaan, 1992; Palombo unpublished data).

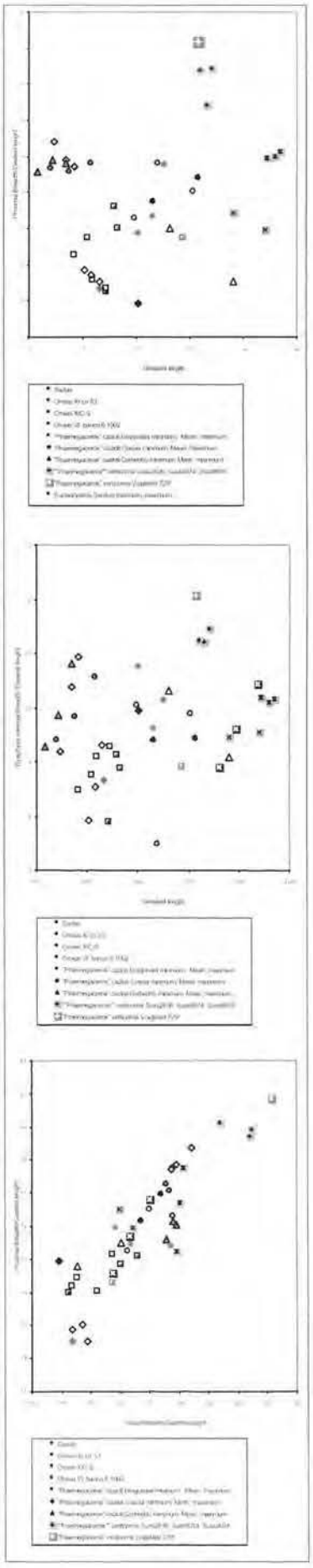

Fig. 12. Metacarpians– Diagrames de dispersió de: a) amplària de l'epífisi proximal respecte la llargària màxima del metacarpià; b)amplària mínima de la canya (diàmetre antero-posterior) respecte el diàmetre transversal distal del metacarpià c) amplària de l'epífisi distal respecte la llargària màxima del metacarpià; d) diàmetre antero-posterior respecte el diàmetre transversal de la part distal del metacarpià a "Praemegaceros" *n. sp. De la Cova Su Fossu de Cannas,* "Praemegaceros" cazioti *(Depéret, 1897) de Sardenya (Dragonara, post-Tirrenià; Cova de Su Corbeddu Cave, Tardiglacial, Hofmeijer, 1997) i Còrsega (Cova de Coscia, Darrer Glacial, Pereira & Bonifay, 1998), a cèrvols endèmics de mida mitjana de Sardenya i de Capri i a cèrvols grans seleccionats del Pliocè i Pleistocè d'Europa (Azzaroli & Mazza, 1992; Kahlke, 1956-59; 1958; 1969; Kahlke, 1997; Kostopoulos, 1997; Leonardi & Petronio 1974; 1976; Spaan, 1992; Palombo dades no publicades).*

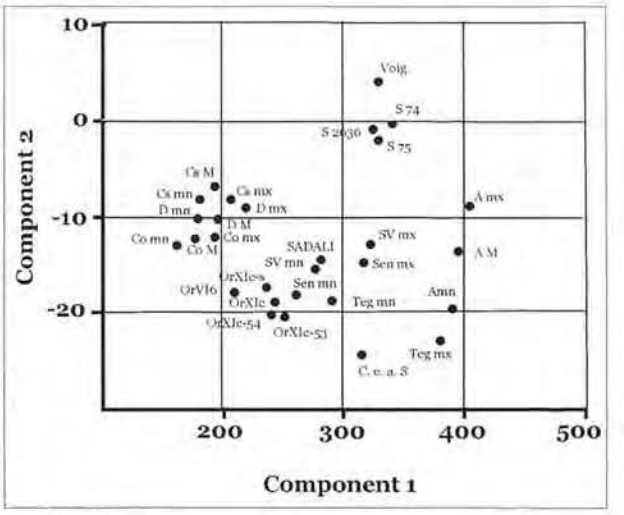

Fig. 13. Principal component diagram. Specimens as in Figure 12.

Fig. 13. Diagrama de Components Principals. Espècimens com a la Figura 12.

muzzle shape and the morphology of the mandible, curved with a short diastema extending upwards. Moreover, metacarpal proportions enable us to hypothesise a possible phylogenetic relationship with the so-called "slender-limbed megacerini" recorded in several localities in the late Early and early Middle Pleistocene in the Mediterranean area (i.e. Venta Micena, Spain, Menendez, 1987; Oubeidiyeh, Israel, Geraards, 1986; Sassa, L'Aquila, Italy, Palombo *et al.*, 2001; Redicicoli, Rome, Italy, Palombo, unpublished data).

The endemic cervids from Sardinian and Corsican Pleistocene deposits were also attributed to the genus *Dama* principally on the basis of their limb proportions (van der Made, 2003; Sondaar 2000, personal communication to M.R.Palombo). Indeed, the author hypothesised that the zeugopodium of this cervid was not shortened, as usually observed in insular artiodactyls. However, it is worth noting that the Su Fossu de Cannas Cave cervid is characterised, with respect to the maximum observed in *"Praemegaceros" cazioti*, by slightly larger mandibular size, proportionally smaller teeth and a shorter premolar row, whereas the metacarpus is of clearly larger dimensions. For the endemic megacerini of Sardinia and Corsica, this fact would suggest a process of allometric reduction in body size, with retarded shortening of the metapodials; accordingly, "*Praemegaceros*" *cazioti* would have, in any case, proportionally shorter metapodials than its ancestor species, contrary to what has already been hypothesised.

Conclusions

The geomorphological context of the area and the morphological and speleogenetic characteristics of the Fossu de Cannas cave lead one to believe that karst phenomena probably began immediately after the emergence of calcareous rocks (Eocene?). Sedimentation inside the cave occurred during successive flooding by tractive

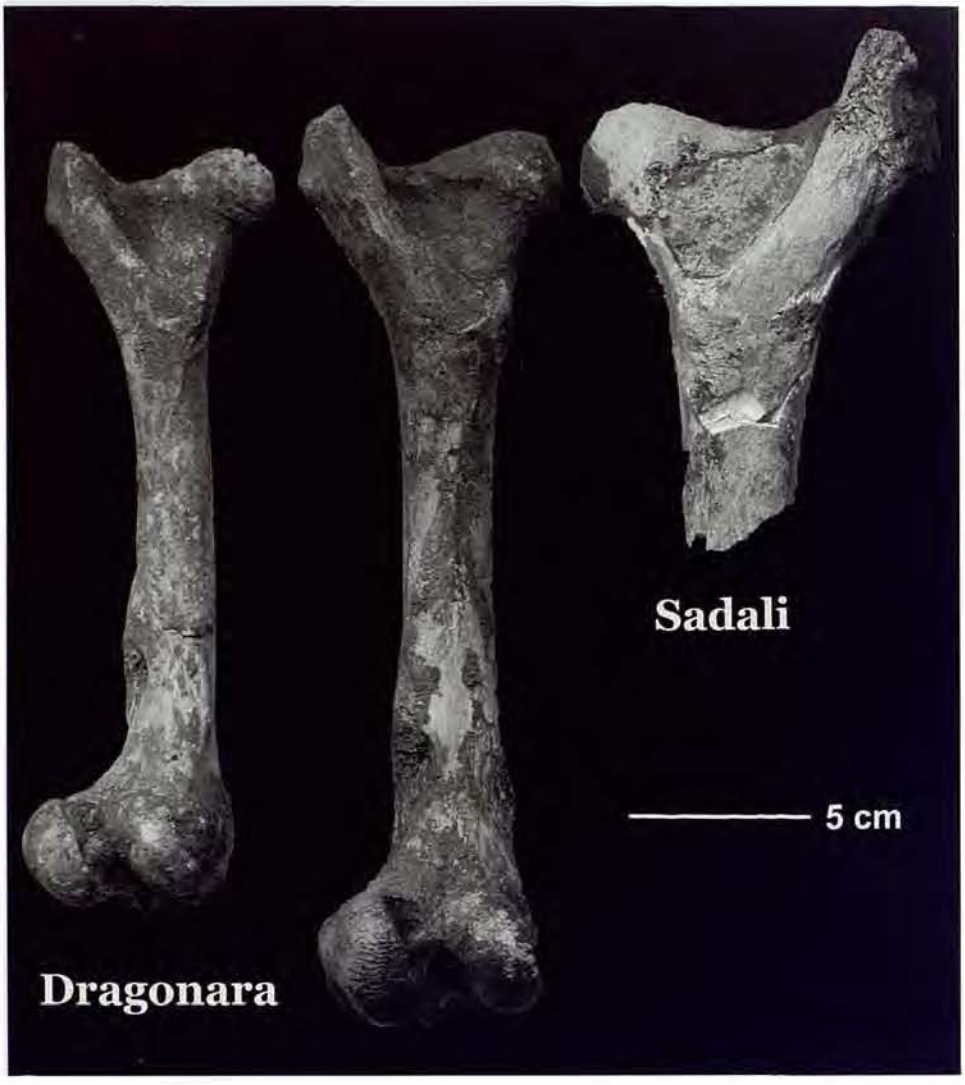

Fig. 14. Plantar view of femur of "*Praemegaceros*" n. sp. from Su Fossu de Cannas Cave compared with the smallest and greatest femora recognised in the sample of "*Praemegaceros*" *cazioti* from Dragonara cave.

Fig. 14. Vista plantar del fèmur de "Praemegaceros" *n. sp. de la Cova Su Fossu de Cannas comparada amb la dels fèmurs més petit i més gran de la mostra de* "Praemegaceros" cazioti *de la Cova Dragonara.*

currents and decantation water, episodes of redeposition of clay masses and concretioning phases. The conglomerate covering the fine sediments and the cervid remains deposited on the surface of the latter indicate that an important erosive phase occurred, probably as a consequence of climatic-environmental change and tectonic movements of considerable importance (late Early Pleistocene?). The presence of this conglomerate would also indicate the external existence of a morphological rise, no longer present, in the area surrounding the cave.

All this points to a hypothesis of very complex speleogenetic evolution, even in view of the long space of time in which karst processes themselves were able to take place. This led to the development of several speleogenetic cycles involving the formation of caves, their filling and subsequent partial demolition, as evidenced by the remains of calcareous flows and stalagmites in the area around the Fossu de Cannas Cave. At present, one can only hypothesise that general filling took place concomitant with cold, damp periods attributable to the late Early/Middle Pleistocene, and demolition of the morphologic rises around the cave during successive alternating hot and cold periods (late Middle Pleistocene-early Late Pleistocene?).

The specimens analysed thus far, whose dimensions exceed the range of variability calculated for the endemic "*Praemegaceros*" *cazioti* species (Depéret, 1897), show close morphological affinities with the endemic Sardinian megalocerine. However, the Sadali cervid differs from the latter in its larger size and in some morphological features (such as the depth and concave horizontal corpus of the mandible and the longer diastema), as well as in its proportionally smaller teeth and, notably, its elongated, slender metacarpal.

The peculiar features of the Sadali specimens suggest its attribution to a new species. Nevertheless, taking into account the richness of the deposit and the fact that numerous remains have not yet been uncovered we prefer, for the moment, to refer the Sadali cervid as "*Praemegaceros*" n. sp, awaiting further data to perfect the diagnosis of this new taxon.

The Su Fossu de Cannas cervid can be regarded as the most primitive representative of the genus "*Praemegaceros*" in Sardinia and as the ancestor of the endemic species "*Praemegaceros*" *cazioti*. Moreover, it is worth noting that the general rule thus far hypothesised for endemic artiodactyls, e.g shortening of *zeugopodium* bones, also seems to be confirmed for the evolu-

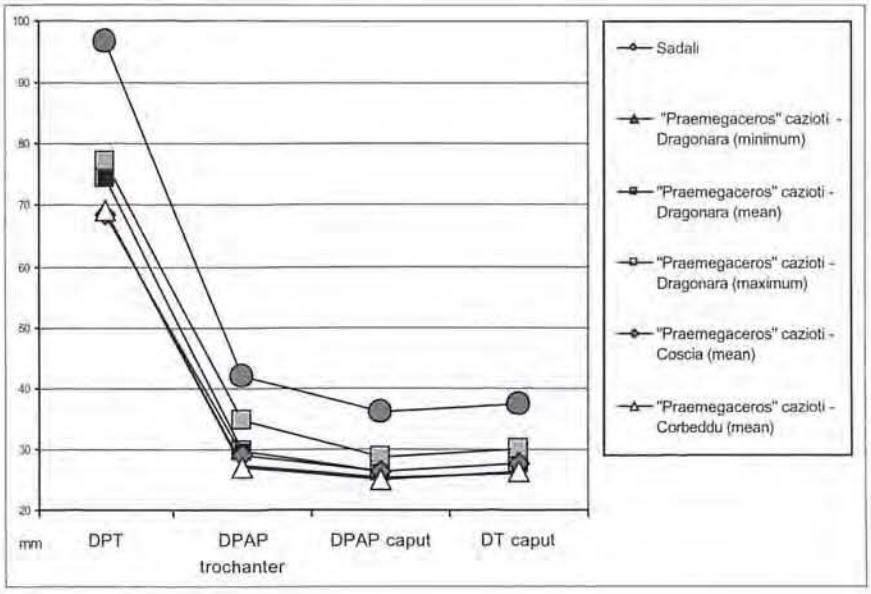

Fig. 15. Femur - Logarithmic distances of the principal dimensional values of the femora of "*Praemegaceros*" n. sp. from Su Fossu de Cannas Cave and of *"Praemegaceros" cazioti* from Dragonara, Corbeddu Cave (Hofmeijer, 1997) and Coscia Cave (Pereira & Bonifay, 1998) (standard = average values of Dragonara sample).

Fig. 15. Fèmur - Distàncies logarítmiques dels principals valors mesurats dels fèmurs de "Praemegaceros" *n. sp. de la Cova Su Fossu de Cannas i de* "Praemegaceros" cazioti *de la Cova Dragonara, Cova de Su Corbeddu (Hofmeijer, 1997) i de la Cova de Coscia (Pereira & Bonifay, 1998) (standard = valors mitjans de la mostra de Dragonara).*

tionary process of Sardinia and Corsica giant deer. Accordingly, metapodial and lower teeth proportions can be regarded as plesiomorphic characteristics, whereas the morphology of the *corpus mandibulae* seems to be apomorphic.

Typical "*Praemegaceros-Tyrrhenicola* fauna" as described in literature (Sondaar, 2000; Sondaar & van der Geer, 2002; Melis & Palombo, this volume), has clearly been documented in Sardinia and Corsica since the Middle Pleistocene. A small-sized species (*Microtus* (*Tyrrhenicola*) sp.), more archaic than Late Pleistocene ones, seems to have been present since the early Middle Pleistocene (van der Made, 1999; Abbazzi *et al.*, 2004; Marcolini *et al.*, 2003; Pereira *et al.*, 2003), whereas no certain date for the first appearance of megacerini in Sardinia is available thus far. Moreover, at Monte Tuttavista, the archaic vole was found in a faunal complex where *Rhagapodemus minor* is still present, whereas "*Praemegaceros*" first occurs together with *Ragamys orthodon*. Accordingly, the entry of the vole might predate that of the cervid. However, in keeping with the size and the proportions of the scanty specimens from the Su Fossu de Cannas Cave, the hypothesis that this cervid might be older than Monte Tuttavista ones cannot be ruled out.

The lack of any micromammal remains, both in the fossiliferous conglomerate and in the other deposits in the Su Fossu de Cannas Cave, makes it difficult to hypothesise which faunal complex the cervid belongs to (but see Palombi, in press).

We hope that ongoing research will clarify the evolution of the cave and the age of fossiliferous deposits, enabling us to better define the biochronological setting and the differentiation process of Sardinian endemic cervid.

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